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Particle Suspension Mechanisms - Supplemental Material

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Supplemental Material: Particle Suspension Mechanisms

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This supplemental material provides a brief introduction to particle suspension mechanisms that cause exfoliated skin cells to become and remain airborne. The material presented here provides additional context to the primary manuscript and serves as background for designing possible future studies to assess the impact of skin cells as a source of infectious aerosols. This introduction is not intended to be comprehensive and interested readers are encouraged to consult the references cited.

Introduction

Exfoliated skin cells settle to the ground due to gravity. In still air, an intact exfoliated skin cell shed 1 m above the ground will deposit on the ground in about 2 minutes.¹ However the mechanisms discussed below counter the forces of gravity and extend the time in which potentially infectious, exfoliated skin cells could pose a respiratory hazard.

Particle Suspension Due to Convective Airflow

In (approximately) still air, an animal's body heat warms the air that immediately surrounds it. The process by which the heated air rises and creates an airflow around and above an animal is called *natural convection*. Natural convection airflow has been extensively studied in humans [S2,S3,S4,S5]. The speed, magnitude, and distribution of natural convection airflow varies about the human body and depends on (a) body shape and orientation and (b) the temperature difference between the skin (or outer clothes) and the environment. Near the skin, airflow velocities exceed the skin-cell settling velocity. Thus exfoliated skin cells are drawn up the body surface and ejected upwards into the greater atmosphere.^{2,3} In livestock, heat loss due to convection is well-documented [S8,S9,S10,S11].

Airflow patterns around livestock (and humans) are clearly more complex than the isolated natural convection case discussed above. Experimental and computational studies have examined these more complex cases [S12,S13,S14,S15,S16]. These studies point to the importance of the following factors: (a) natural and/or mechanical ventilation (outdoor wind; indoor ventilation used to remove livestock-produced pollutants), (b) objects that deflect large-scale airflows (e.g. livestock pens), (c) non-uniform thermal environments (e.g. the sun heats one side of a building, but not the other), and (d) animal physiological responses to the external environment (e.g. perspiration; limited blood flow to the skin resulting in lower skin temperature in cold weather). Several studies [S13,S14,S15,S16] report airflow around simulated livestock greater than the skin cell gravitational settling velocity. These studies also demonstrate that natural convection can mix otherwise still air (e.g. air next to animals huddled against a pen partition) into the dominant building airflows.⁴

¹ This assumes a skin cell settling velocity equal to a 15 μm aerodynamic-diameter particle (0.007 m s^{-1}) [S1].

² Preliminary experiments [S6] (a) demonstrate more microorganisms in the air next to the skin than in the surrounding atmosphere and (b) an order of magnitude increase in microorganism concentration in air next to the skin after scratching the skin upwind (below) of the measurement location.

³ Due to the human's upright posture, natural convection airflows can also draw material deposited on the ground up to the breathing zone [S7].

⁴ Particles suspended in the dominant building airflow can then travel within the building and/or be vented to the outside atmosphere.

Particle Resuspension

The resuspension of material deposited on the ground back into the atmosphere has been studied in a number of settings. These settings include studies of human health impacts, of dust/dirt movement, of the spread of radioactive contamination, of disease transmission, as well as studies of natural biological aerosols [S17,S18,S19,S20,S21,S22]. Like the complex airflows discussed above, many factors can influence resuspension rates. These include (but are not limited to) the: (a) physical resuspension process (e.g. mechanical disturbances⁵, wind), (b) characteristics of the resuspended particle (e.g. aerosol size and chemical properties), (c) the surface from which the particle resuspends⁶ (e.g. soil, vegetation), and (d) the age of the deposited material. Due to the large number of potentially important explanatory variables, each of which has a significant range of variability, observed resuspension rates have a wide range of variation (up to 8 orders of magnitude) [S22]. While a robust and comprehensive resuspension model has yet to be developed (e.g. [S26]), empirical models are available for specialized applications [S27,S28,S29].

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⁵ Animal activity is effective in (re)suspending dust [S23,S24,S25].

⁶ High (> 70%) relative humidity and/or wet surfaces reduce resuspension rates [S23,S24,S25].

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